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DATA ACQUISITION AND CONTROL SYSTEM OF HYDROELECTRIC POWER PLANT USING INTERNET TECHNIQUES

SYSTÉM SNÍMÁNÍ DAT A OVLÁDÁNÍ VODNÍ ELEKTRÁRNY PROSTŘEDNICTVÍM INTERNETOVÉ TECHNIKY

SHORT VERSION OF PhD. THESIS

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1 INTRODUCTION

The widespread application of Renewable Energy Sources (RES) requires the use of internet techniques both for monitoring system operation and control of its operation. In this paper, the development of a data acquisition system for remote monitoring and control of hydroelectric power plant plants is presented. It is based on switched Ethernet network.

The advantages of networking in control systems are so strong that any systems above some minimal level of complexity are likely to utilize networking. There are many motivations for wanting computer networks in a control system, additional computing power and distribution of computing to match the target system‘s topology. There are also the motivation of data and information integrity and reduced cabling. Traditional control systems relied on analog information transmission, both for sensing and for actuation. Analog cables carry one signal per cable. Analog signals are also susceptible to contamination from a variety of noise sources. Operationally, digital signals can have arbitrarily strong protection against noise. Furthermore, the cost of that protection scales reasonably with the severity of the noise. Overall system cost is another major motivation for networked control systems.

Fig. 1.1 shows a block diagram of Data Acquisition (DAQ) and control system of any actual system or plant. Data acquisition stores data in database server or database node in format that can be easily retrievable engineering, scientific review, costs and economical analysis, fualt analysis, maintenance analysis and others. The system illustrated is the presented and simulated system in this thesis for hydroelectric power plant, which is consists of synchronous generetor, excitation system and hydrualic turbine.

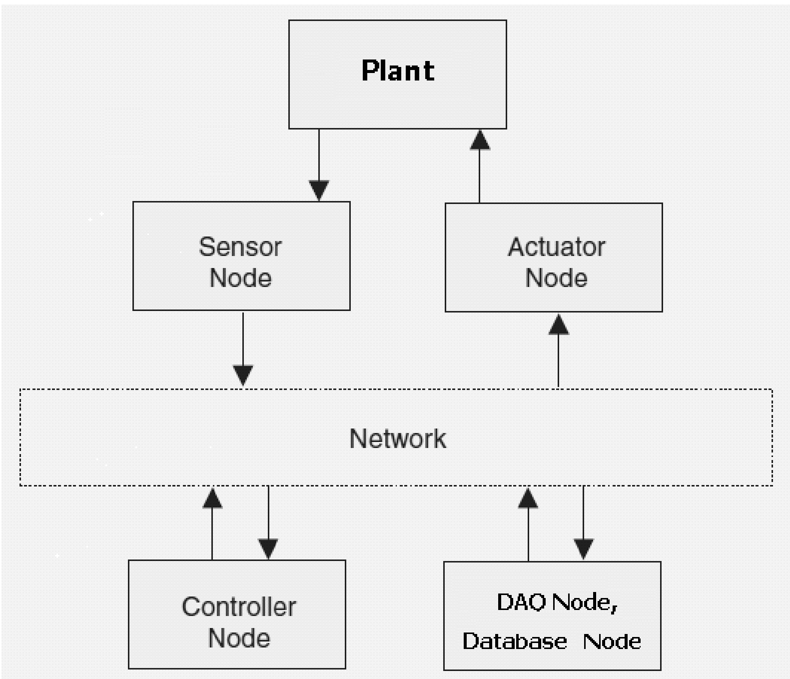

Fig. 1.1: Network control and DAQ system

2 DATA ACQUISITION SYSTEMS

DAQ (Data AcQuisition) is simply the process of bringing a real-world signal, such as avoltage, into the computer, for processing, analysis, storage or other data manipulation. A Physical phenomena represent the real-world signal which is measured. In order to optimize the characteristics of a system in terms of performance, handling capacity and cost, the relevant subsystem can be combined together.

Most real-world data are not in a form that can be directly recorded by a computer. These quantities typically include temperature, pressure, distance, velocity, mass, and energy output (such as optical, acoustic, and electrical energy). Very often these quantities are measured versus time or position. A physical quantity must first be converted to an electrical quantity (voltage, current, or resistance) using a sensor or transducer. This enables it to be conditioned by electronic instrumentation, which operates on analog signals or waveforms (a signal or waveform is an electrical parameter, most often a voltage, which varies with time). This analog signal is continuous and monotonic, that is, its values can vary over a specified range (for example, somewhere between -5.0 volts and +3.2 volts) and they can change an arbitrarily small amount within an arbitrarily small time interval.

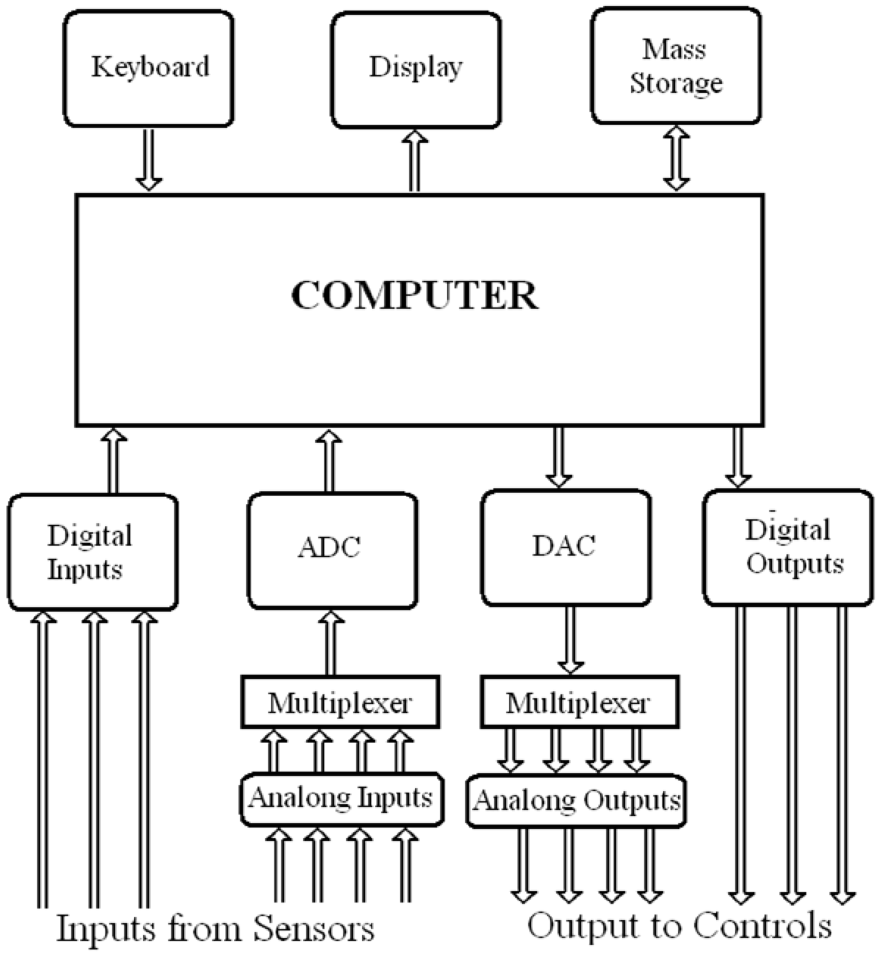

Fig.2.1: Block diagram of DAQ system

Analog data is generally acquired and transformed into the digital form for the purpose of processing, transmission and display. Rapid advances in Personal Computer (PC) hardware and software technologies have resulted in easy and efficient adoption of PCs in various precise measurement and complex control applications. A PC based measurement or control application requires conversion of real world analog signal into digital format and transfer of digitized data into the PC.

The process of converting an analog signal to a digital one is called analog-to-digital conversion, and the device that performs this is an analog-to-digital converter (ADC). The resulting digital signal is usually an array of digital values of known range (scale factor) separated by a fixed time interval (or sampling interval). If the values are sampled at irregular time intervals, the acquired data will contain both value and time information. The reverse process of converting digital data to an analog signal is called digital-to-analog conversion, and the device that does this is called a digital-to-analog converter (DAC). Some common applications for DACs include control systems, waveform generation and speech synthesis.

A general-purpose laboratory data acquisition system typically consists of ADCs, DACs, and digital inputs and outputs. Fig. 2.1 shows a block diagram of DAQ system.

The additional channels are often added to an ADC via a multiplexer, used to select which one of the several analog input signals to convert at any given time. This is an economical approach when all the analog signals do not need to be simultaneously monitored.

2.1 Transducers

Most real-world events and their measurements are analog. That is, the measurements can take on a wide, nearly continuous range of values. The physical quantities of interest can be as diverse as heat, pressure, light, force, velocity, or position. To be measured using an electronic data acquisition system, these quantities must first be converted to electrical quantities such as voltage, current, or impedance.

2.1 Signal conditioning

Nearly all transducer signals must be conditioned by analog circuitry before they can be digitized and used by a computer. This conditioning often includes amplification and filtering, although more complex operations can also be performed on the waveforms.

Amplification (or occasionally attenuation) is necessary for the signal's amplitude to fit within a reasonable portion of the ADC's dynamic range. Also filtering must usually be performed on analog signals for several reasons. Sometimes noise or unwanted signal artifacts can be eliminated by filtering out certain portions of the signal's spectra. A low-frequency drift on a signal without useful DC information can be removed using a high-pass filter. Most often, low-pass filters are employed to limit the high end of a waveform's frequency response just prior to digitization, to prevent aliasing problems. Additional analog signal processing functions include modulation, demodulation, and other nonlinear operations.

2.2 Analong / digital conversion

Analog-to-Digital Converters (ADCs) transform an analog voltage to a binary number (a series of 1’s and 0’s), and then eventually to a digital number (base 10) for reading on a meter, monitor, or chart. The number of binary digits (bits) that represents the digital number determines the ADC resolution. However, the digital number is only an approximation of the true value of the analog voltage at a particular instant because the voltage can only be represented (digitally) in discrete steps. How closely the digital number approximates the analog value also depends on the ADC resolution.

A mathematical relationship conveniently shows how the number of bits an ADC handles determines its specific theoretical resolution: An n-bit ADC has a resolution of one part in 2^{n}, For example, a 12-bit ADC has a resolution of one part in 4,096, where $2^{12} = 4{,}096$. Thus, a 12-bit ADC with a maximum input of 10 Vdc can resolve the measurement into $\frac{10}{4096}\text{Vdc} = 0.00244\ \text{Vdc} = 2.44\text{mV}$.

Some of the more common ADCs are Ramp ADC, Successive-Approximation ADC, Dual-Slope ADC, Voltage-to-Frequency Converter, Flash ADC and Sigma-Delta Converter.

The most important ADC parameters are resolution and sampling rate. In practice, an ADC's sampling rate should be much higher than twice the maximum signal frequency. A value of five times is a good choice. In most data acquisition systems, the analog input is filtered to eliminate any signal components above the Nyquist frequency. This is often referred to as an anti-aliasing filter. For such a low-pass filter to produce adequate attenuation at the Nyquist frequency, it should have a cut off frequency well below that point, requiring a sampling rate many times higher than the maximum frequency of interest.

Digital-To-Analog Converters (DACs) transform digital values to analog signals. DACs use either current or voltage switching techniques to produce an output analog value equal to the sum of several discrete analog values. Because it is easier to sum currents (rather than voltages) using analog circuitry, most commonly available DACs are current-mode devices. They produce the sum of internal current sources and use either an internal or external op amp as an output current-to-voltage converter.

Most common types of DACs are Fully Decoded DAC, Weighted Resistor DAC, Resistor Quad DAC and R-2R Ladder DAC. Fig. 2.4 shows 8-bit DAG using R-2R resistor ladder.

2.3 DAQ systems using internet

The recent growth of networks and especially the spread of the Internet have boosted the development of distributed measurement systems for a variety of applications. Most distributed measurement systems follow the Client/Server architecture, as illustrated in Fig.2.2. According to this architecture, one or more instruments are connected to a measuring station, which operates as a server, while the acquired data are available through a network to the clients.

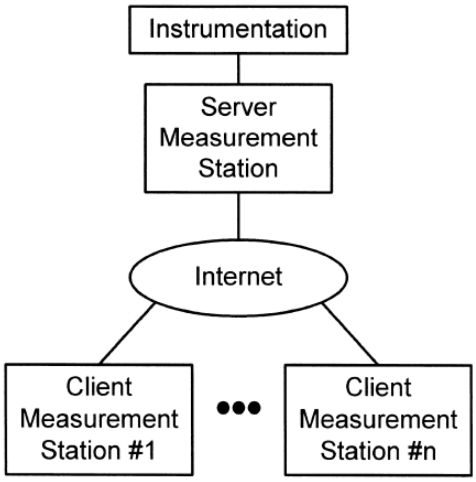

Fig.2.2: Distributed measurement system based on Client/Server architecture

3 NETWORKED CONTROL SYSTEMS

Networked control systems (NCS) have been one of the main research focuses in academia as well as in industrial applications for many decades. A control system is a device or set of devices to manage, command, direct or regulate the behavior of other devices or systems.

The classical definition of NCS can be as follows: When a traditional feedback control system is closed via a communication channel, which may be shared with other nodes outside the control system, then the control system is called an NCS. An NCS can also be defined as a feedback control system wherein the control loops are closed through a real-time network. The defining feature of an NCS is that information (reference input, plant output, control input, etc.) is exchanged using a network among control system components (sensors, controllers, actuators, etc., see Fig.3.1).

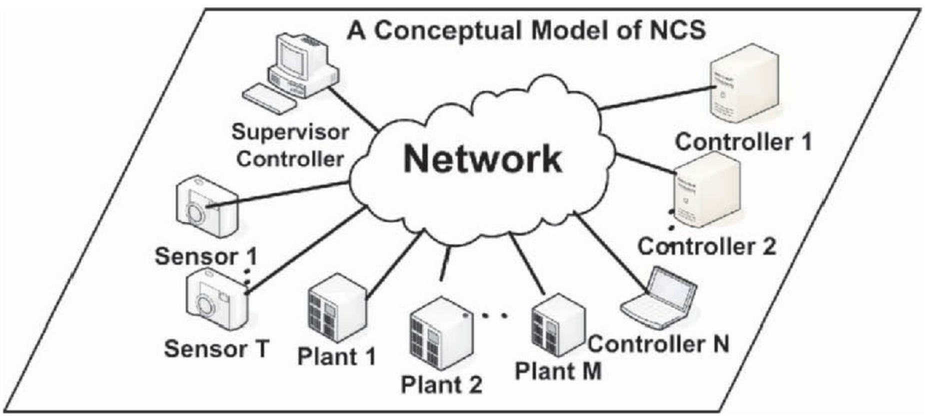

Fig.3.1: Typical Networked Control System

For many years now, data networking technologies have been widely applied in industrial and military control applications. These applications include manufacturing plants, automobiles, and aircraft. Connecting the control system components in these applications, such as sensors, controllers, and actuators, via a network can effectively reduce the complexity of systems, with nominal economical investments. Furthermore, network controllers allow data to be shared efficiently. It is easy to fuse the global information to take intelligent decisions over a large physical space. They eliminate unnecessary wiring. It is easy to add more sensors, actuators and controllers with very little cost and without heavy structural changes to the whole system. Most importantly, they connect cyber space to physical space making task execution from a distance easily accessible These systems are becoming more realizable today and have a lot of potential applications including factory automation, remote diagnostics and troubleshooting, hazardous environments and many other applications.

NCS components have to enable four functions which form the basis of the function an NCS is required to project. These basis functions are information acquisition (sensors), command (controllers), and communication and control (actuators).

The two major types of control systems that utilize communication networks are shared-network control systems and remote control systems. Using shared-network resources to transfer measurements, from sensors to controllers and control signals from controllers to actuators, can greatly reduce the complexity of connections. This method provides more flexibility in installation, and eases maintenance and troubleshooting. a remote control system can be thought of as a system controlled by a controller located far away from it. This is sometimes referred to as tele-operation control. Remote data acquisition systems and remote monitoring systems can also be included in this class of systems. The place where a central controller is installed is typically called a “local site”, while the place where the plant is located is called a “remote site”.

4 INTERNET NETWORK MODEL/TRUETIME

TrueTime is a Matlab/Simulink-based simulator for networked and embedded control systems that has been developed at Lund University since 1999. The simulator software consists of a Simulink block library and a collection of MEX files. The kernel block simulates a real-time kernel by executing user-defined tasks and interrupt handlers. The various network blocks allow nodes (kernel blocks) to communicate over simulated wired or wireless networks. Fig. 4.1 shows TrueTime block library of Trutime 2.0 beta 6 2010 version.

The TRUETIME blocks are connected with ordinary Simulink blocks to form a realtime control system. Before a simulation can be run, however, it is necessary to initialize kernel blocks and network blocks, and to create tasks, interrupt handlers, timers, events, monitors,.. etc for the simulation. The initialization code and the code that is executed during simulation may be written either as Matlab M-files or as C++ code

The execution of tasks and interrupt handlers is defined by code functions. A code function is further divided into code segments according to the execution model shown in Fig. 4.2. All execution of user code is done in the beginning of each code segment. The execution time of each segment should be returned by the code function.

The standalone network blocks, named TrueTime Send and TrueTime Receive, as seen in Fig. 4.1, can be used to send messages using the network blocks without using kernel blocks. This makes it possible to create TrueTime network simulations without having to initialize kernels.

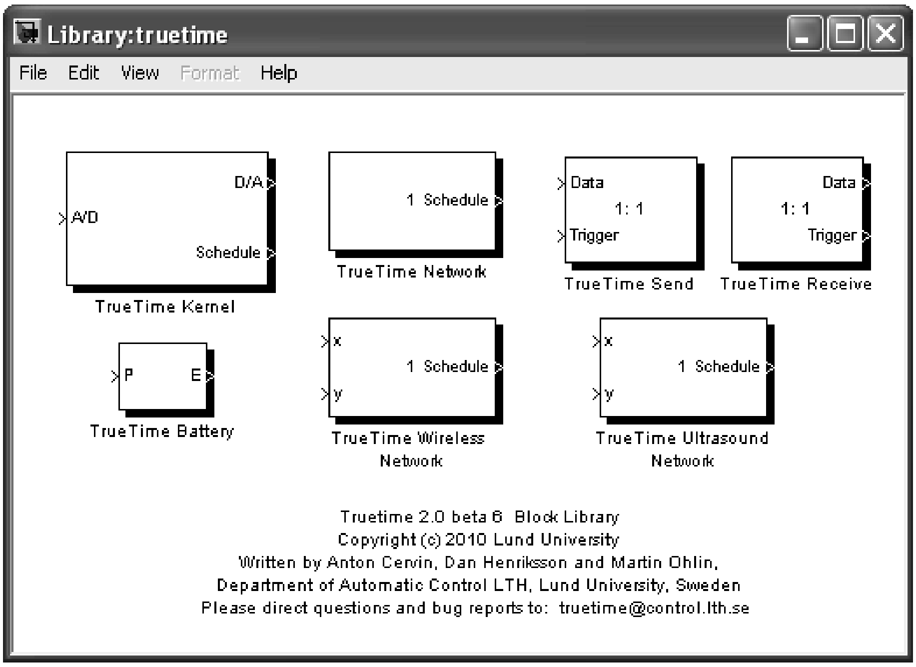

Fig.4.1: TrueTime block library

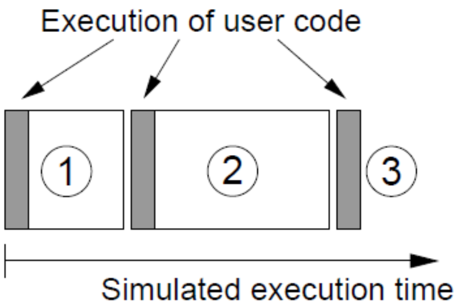

Fig. 4.2: Execution of user code and sequence of segments

The TrueTime Battery block acts as a power source for the battery enabled kernel blocks. It uses a simple integrator model so it can be both charged and recharged. The only one parameter in its block mask is the initial power. TrueTime Ultrasound Network and TrueTime Wireless Network blocks are used to simulate wireless networks

The TrueTime Network block simulates medium access and packet transmission (physical and medium access layer) in a local area network. The following subsections describe TrueTime Network and TrueTime Kernel blocks in some detail.

5 SIMULATION AND RESULTS

5.1 Three phase synchronous generator steady-state model

This subsection shows simulation results of implementing of three phase synchronous generator steady-state model. Voltages v_a, v_b and v_c applied to stator windings are three balanced phases which are:

$$v_a = v_m \cos(\omega t) \tag{8.1}$$

$$v_b = v_m \cos(\omega t - \frac{2\pi}{3}) \tag{8.2}$$

$$v_c = v_m \cos(\omega t + \frac{2\pi}{3}) \tag{8.3}$$

In this case the operation conditions are simiral to conditions in which the generator is connected directly to infinite network with neglected ohmic and inductance resistant of the network.

Fig. 5.1 and Fig. 5.2 show *simulation 1* results of implementing mechanical torque of 0.8 pu in the begining of simulation, 0 pu at time 3 s, 1 pu at time 6 s and finally 0.5 pu at time 9 s until simulation end. The field voltage implemented during simulation is constant at 1 pu.

Fig. 5.3 and Fig. 5.4 show *simulation 2* results of changing the field voltage implemented to field winding by 20% steps, that's mean implementing field voltage of 1 pu in the begining of simulation, 0.8 pu at time 3 s, 1 pu at time 6 s and finally 1.2 pu at time 9 s until simulation end. The mechanical torque implemented during simulation is constant at 0.8 pu.

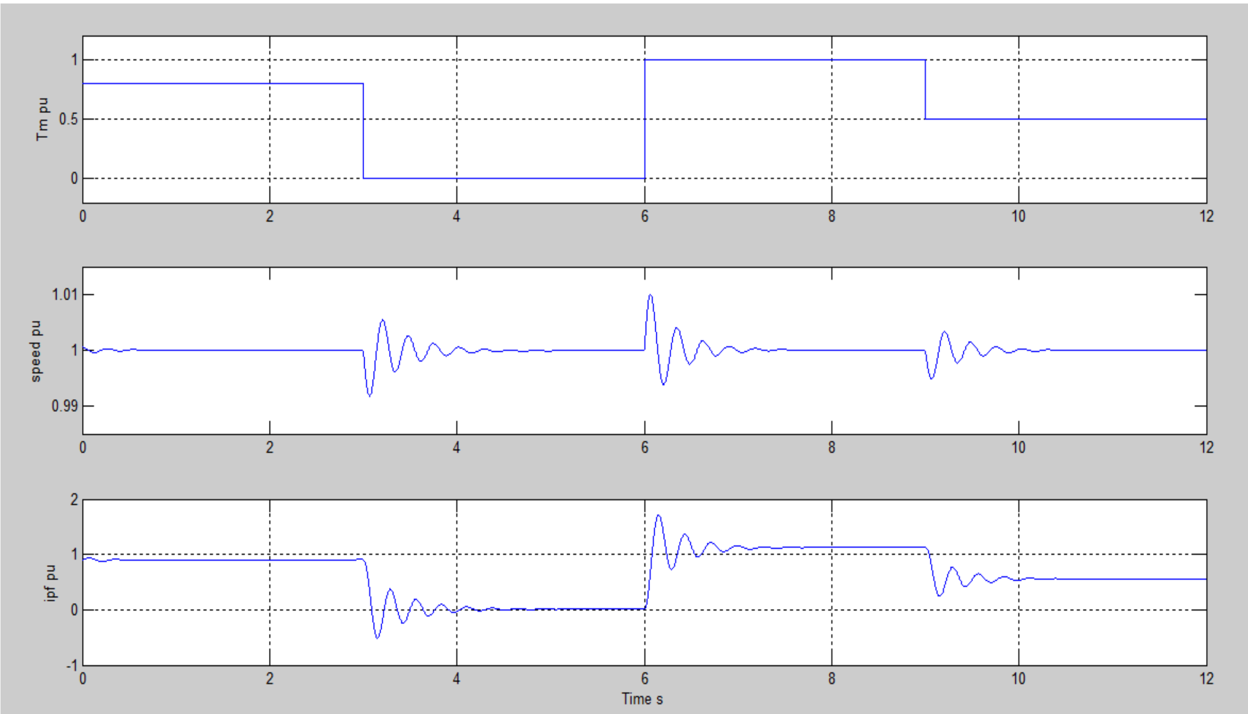

Fig. 5.1: Torque, speed and field current results of *simulation 1* in pu.

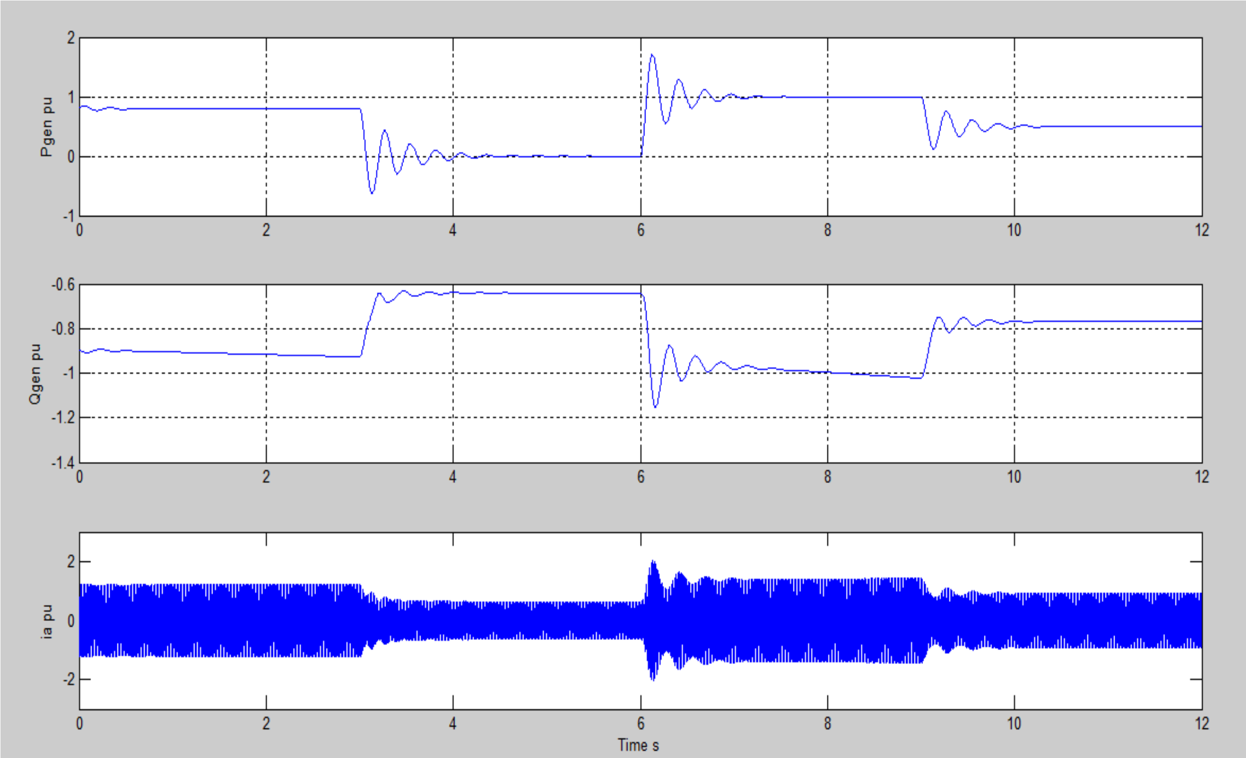

Fig. 5.2: Active power, reactive power and phase a current results of *simulation 1* in pu.

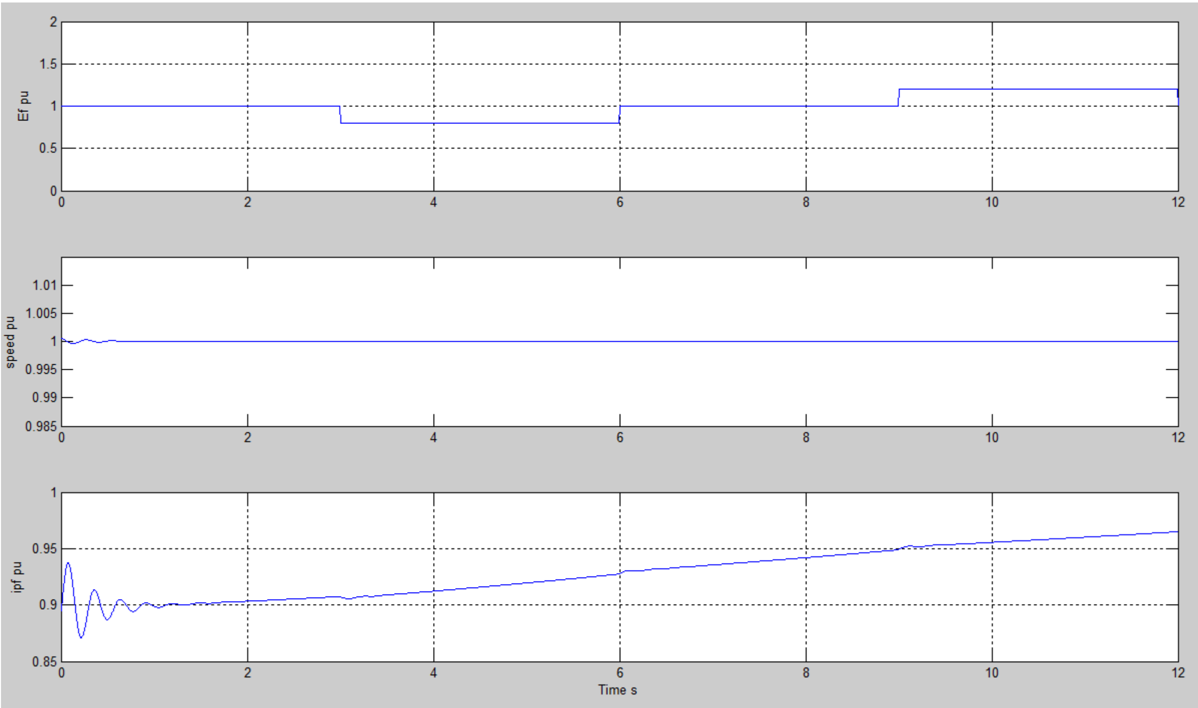

Fig. 5.3: Torque, speed and field current results of *simulation 2* in pu.

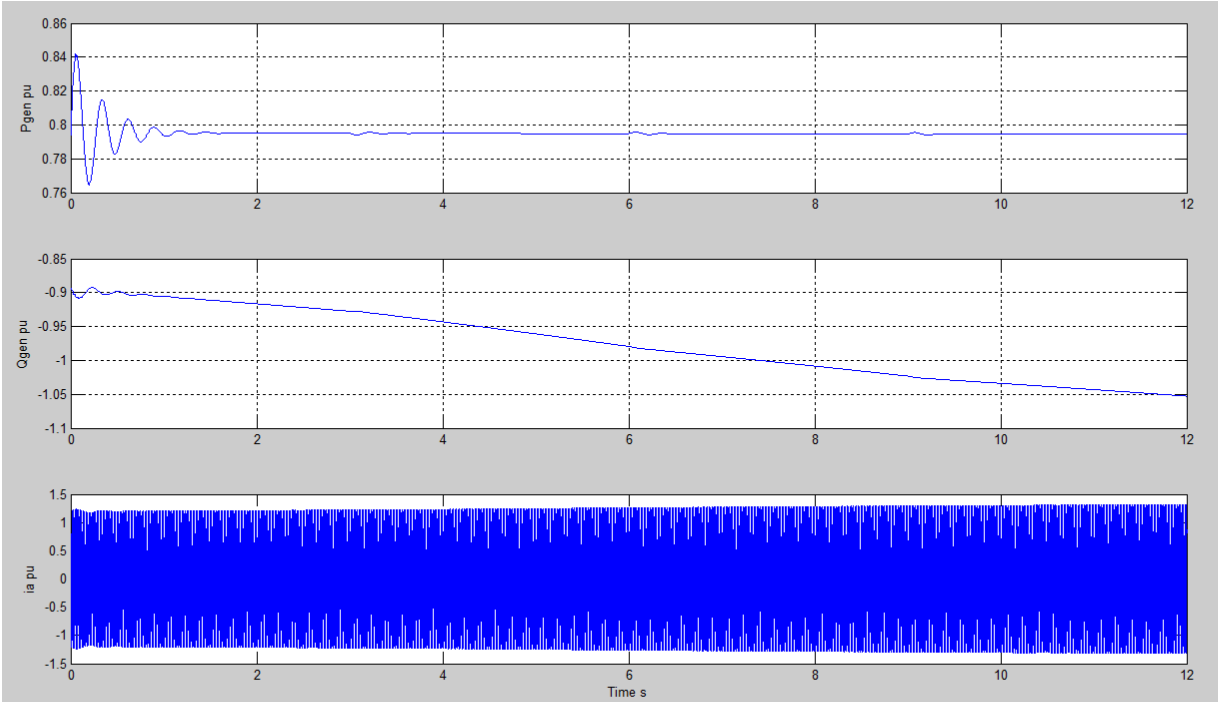

Fig. 5.4: Active power, reactive power and phase a current results of *simulation 2* in pu.

5.2 Three phase synchronous generator transient model/ hydro power plant model

In this subsection we will show simulation results of implementing three phase synchronous generetor transient model with excitation system and hydrualic turbine.

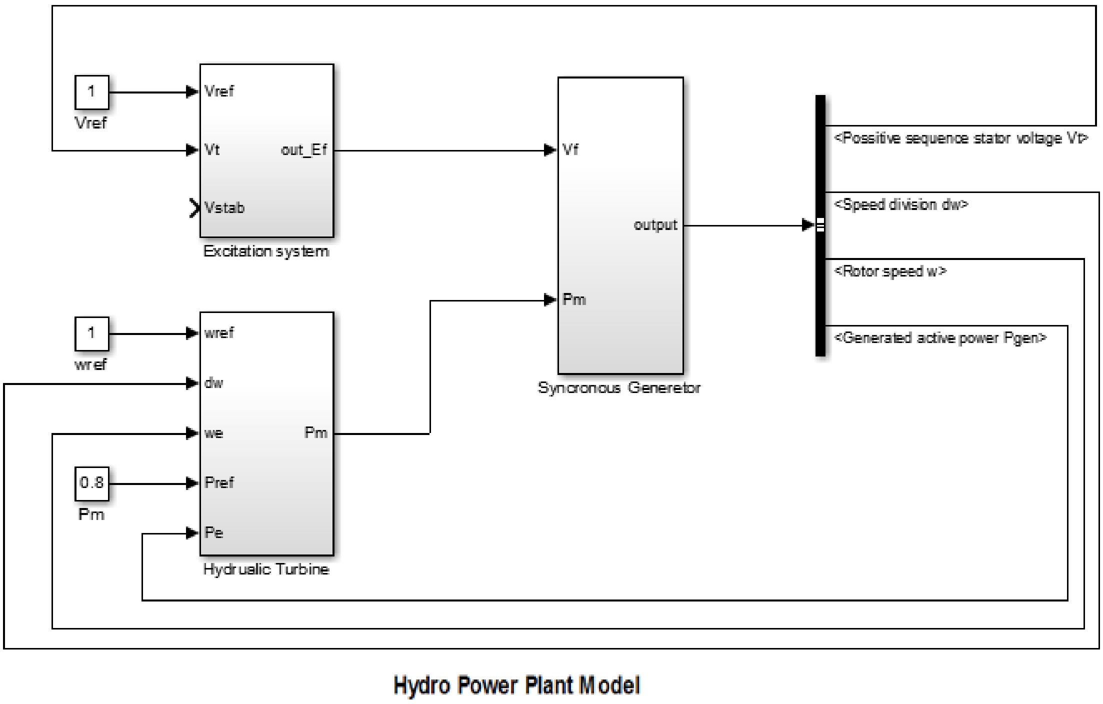

Fig. 5.5: Overall diagram of hydro power plant

Fig. 5.5 shows overall diagram of this project, while Fig. 5.6 shows the hydraulic turbine time response for changing in reference power input from 0.8 pu to 0.5 pu at time 10 s.

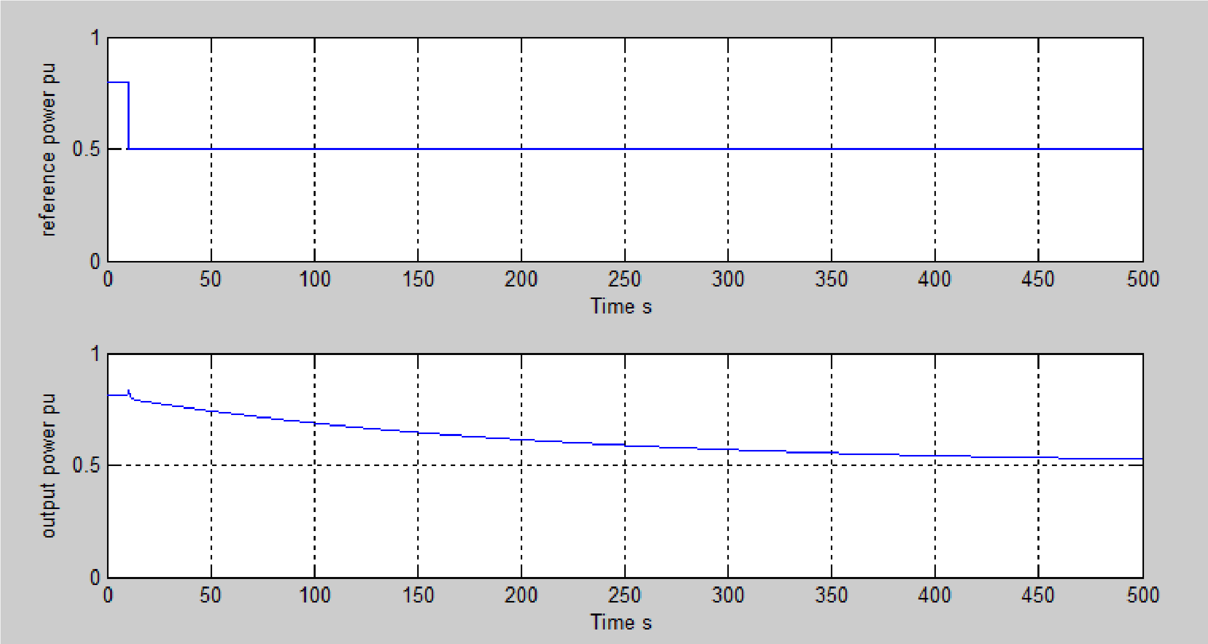

Fig. 5.6: Turbine response

The following figures, Fig. 5.7, Fig. 5.8 and Fig.5.9, show the transient response results of implementing three phase fault on the generator terminals at time 5s, the fault duration is 0.1s.

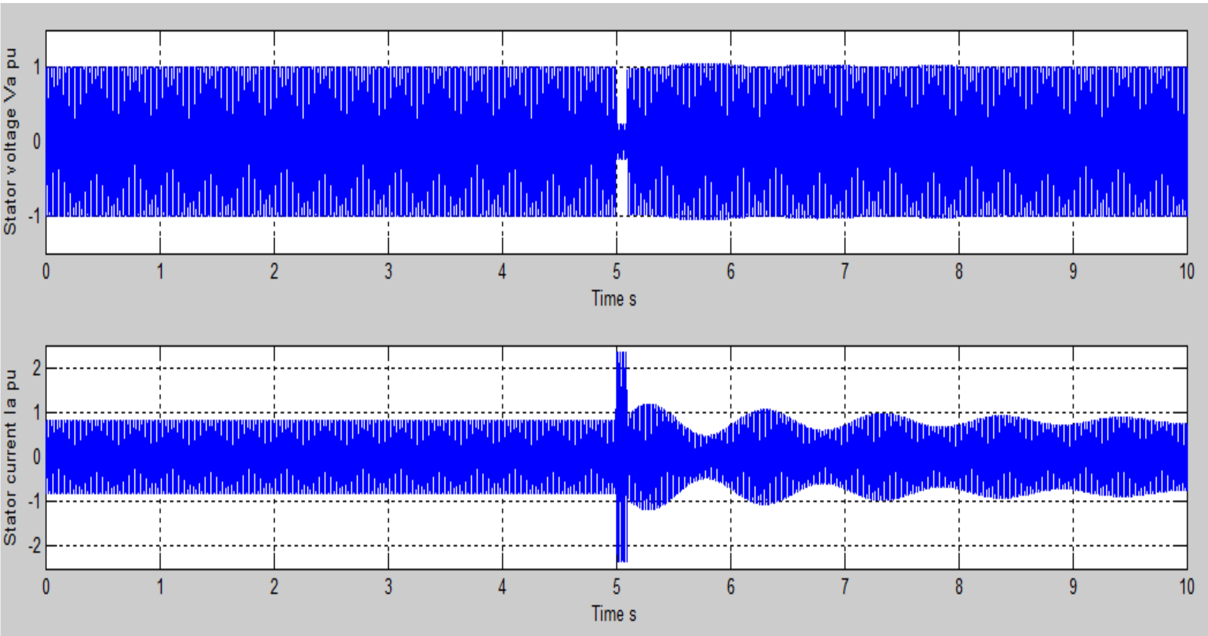

Fig. 5.7: Stator voltage Va and current Ia with fault at time 5s

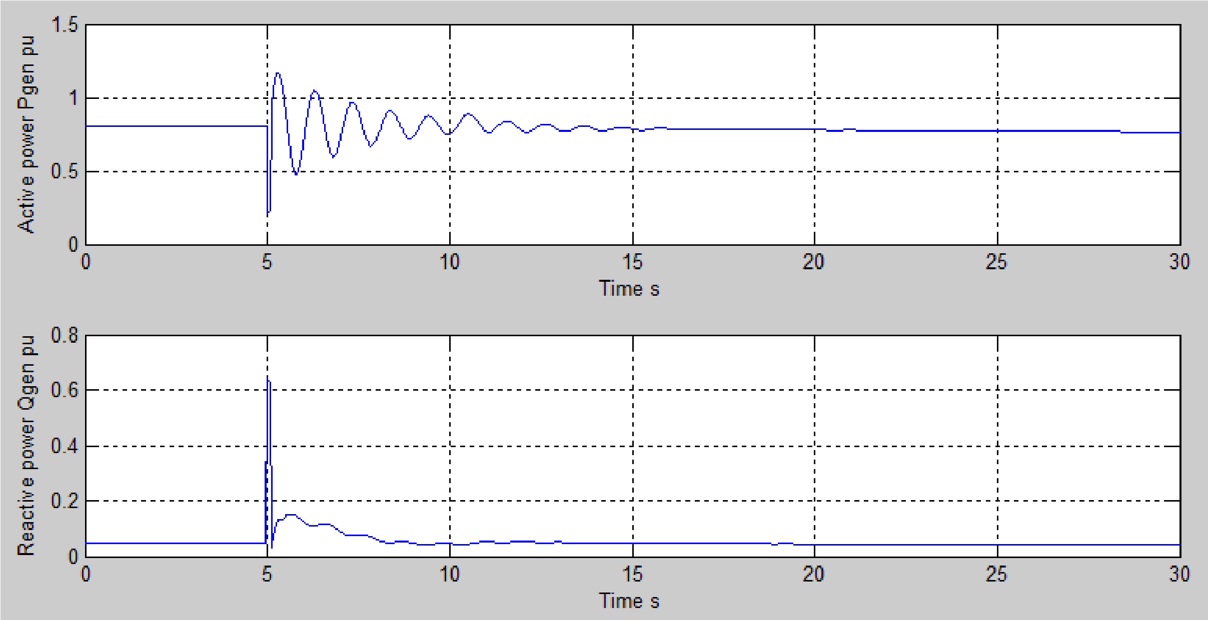

Fig 5.8: Active power Pgen and reactive power Qgen with fault at time 5s

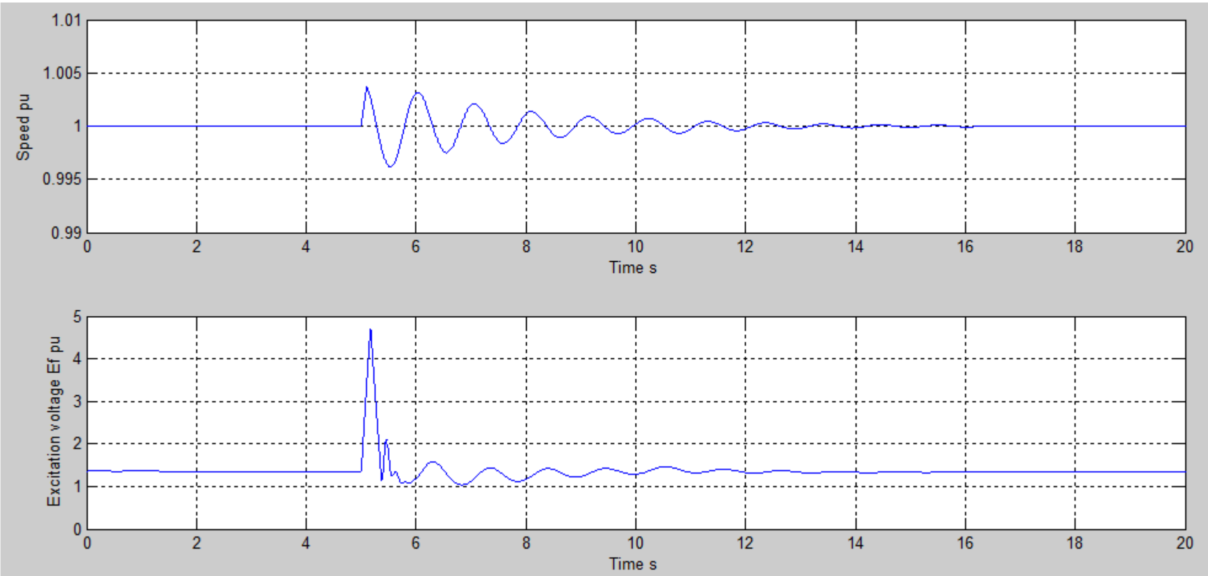

Fig. 5.9: Speed and excitation voltage with fault at time 5s

Now we will show the effect of using power system stabilizer PSS on damping the oscillation occured after fault.

Fig. 5.10 and Fig 5.11 show show simulation results of speed, excitation voltage, active power and reactive power with using of PSS. In this case the generator will settle in about 4 s after fault (Fig.5.10 and Fig. 5.11), compairing with about 10s in the case without using of PSS (Fig 5.8 and Fig. 5.9).

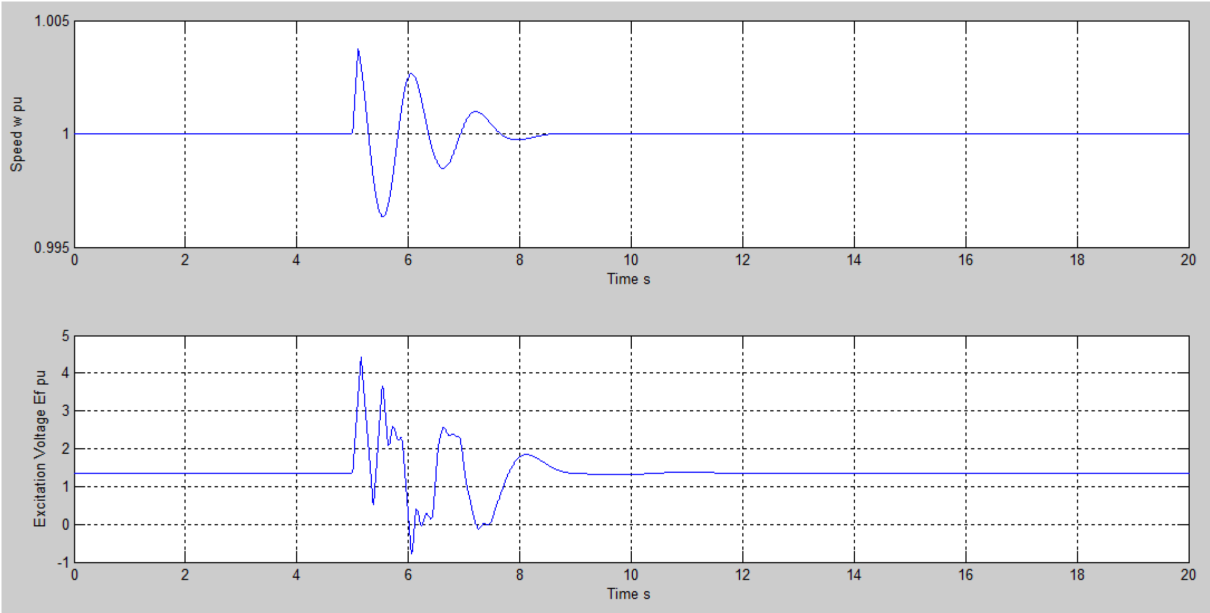

Fig. 5.10: Speed and excitation voltage results with using of PSS. (fault at time 5s)

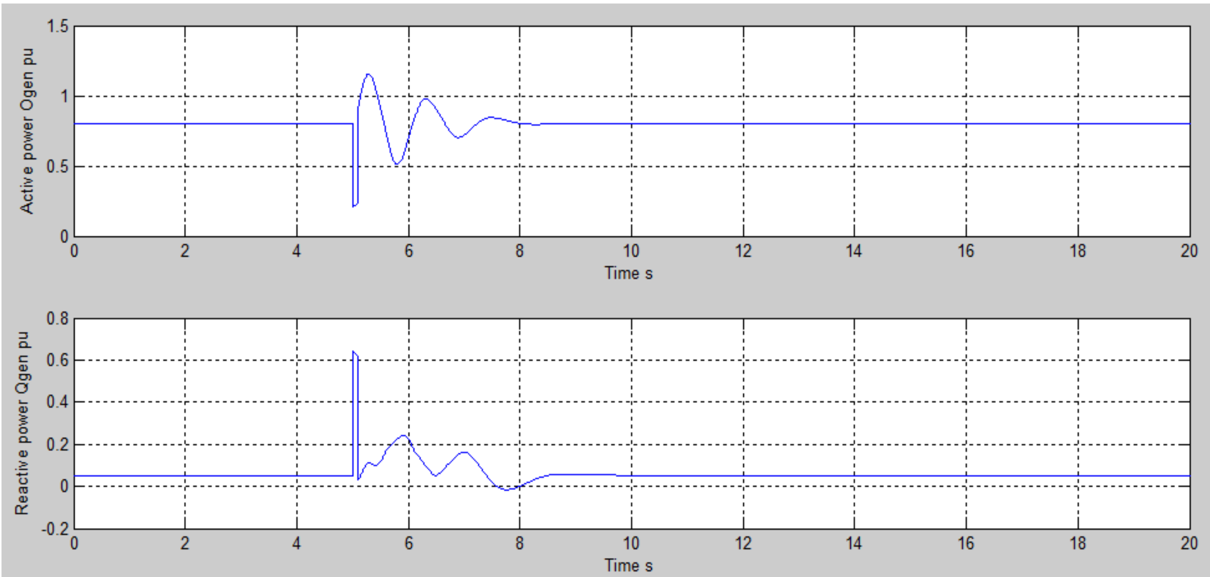

Fig. 5.11: Active power Pgen and reactive power Qgen results with using of PSS.(fault at time 5s)

5.3 Data aqcuisation system of power plant over internet network

Fig. 5.12 shows overall diagram of hydro power plant with data aqcuisation system using internet network.

TrueTime Simulink library was used to simulate the internet network. Network type Switched Ethernet was used in this simulation. Fig. 5.13 shows inside the network block, which is consists of three nodes.

1- **Data aqcuisition node**: It recieves all signale from the plant, converts it to digital signals and sends it to actuator and database nodes.

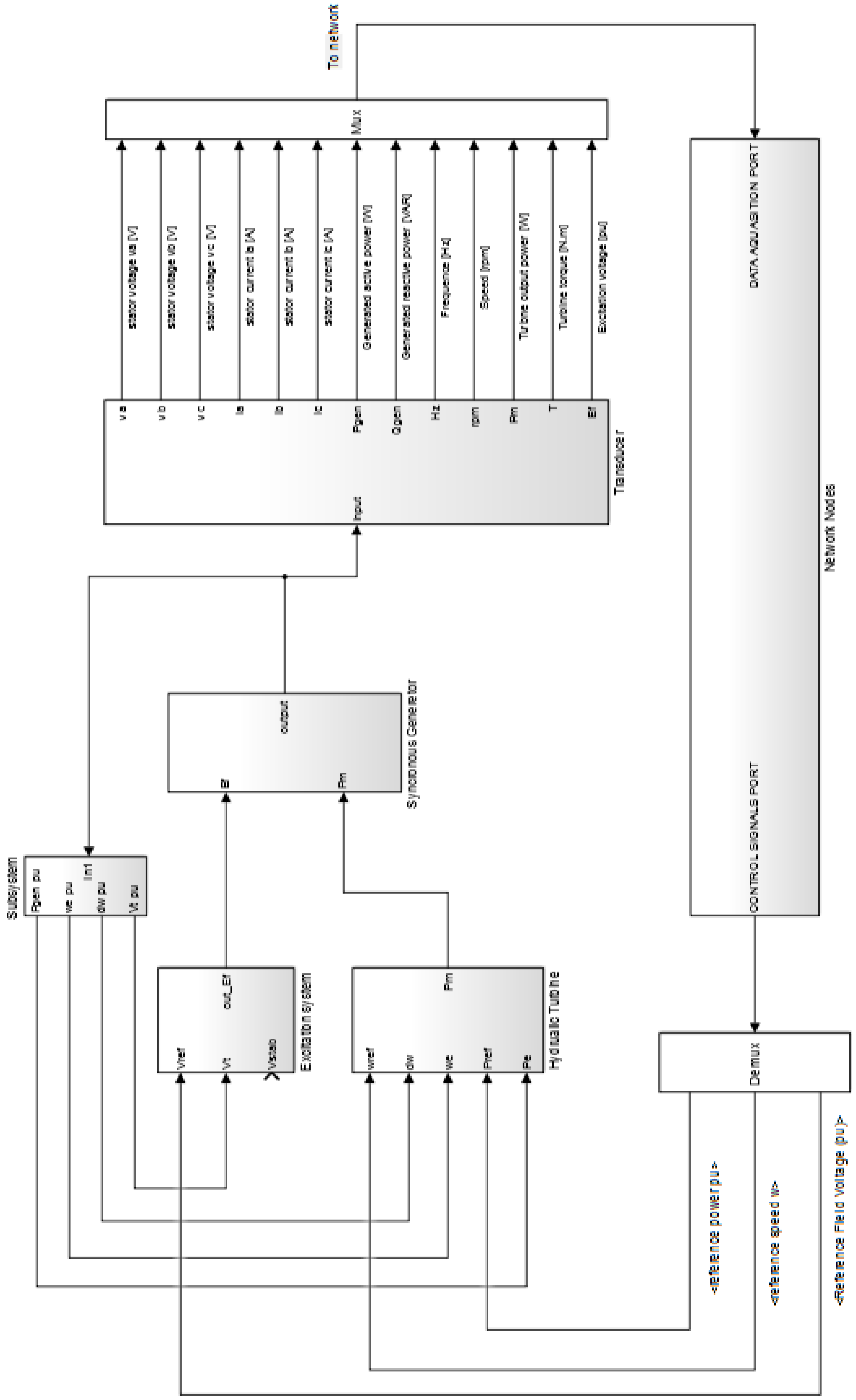

Fig. 5.12: Data Aqcuisition system of hydro power plant using internet network.

2- **Actuator node**: It convert control signals to analog form and sends it to the plant, control signals in this case are reference values of turbine mechanical power, speed and field voltage.
3- **Database node**: It recieves signals from Data aqcuisition node, and store them in database server that they can be restored and analysed in any time.

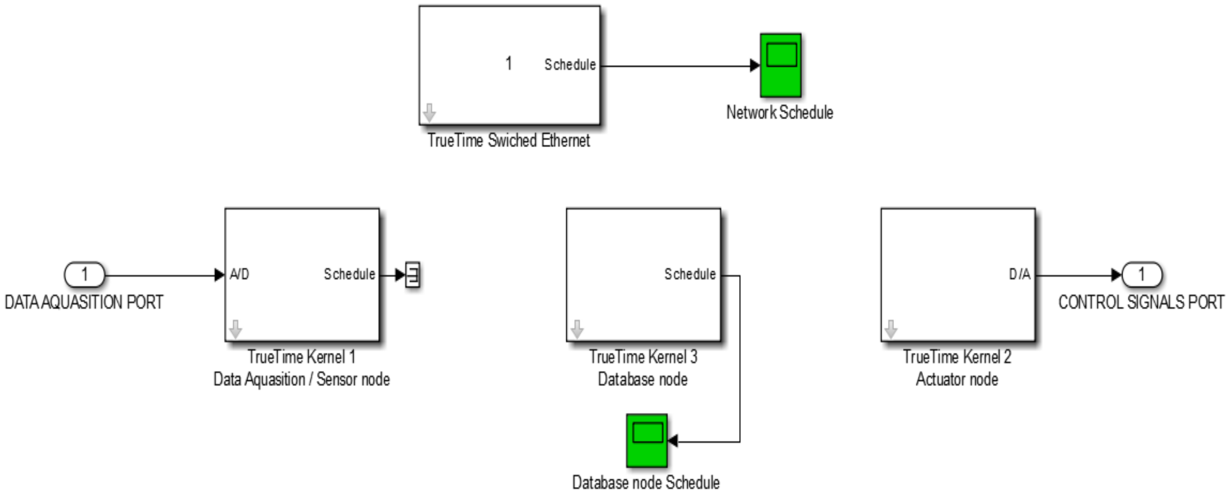

Fig.5.13: Inside internet subsystem.

While the used frequency for generator is 60 Hz, so using sampling time of 0.002s and less for data aqcuasition will be acceptable. In this simulation the used sampling time is 0.001s, which mean about 16 samples during each cycle of the 60 Hz signals.

Fig. 5.14, Fig. 5.15 and Fig. 5.16 show the stored data of stator voltage va, stator current ia and frequency respectivly, the results are shown before, during and after the fault.

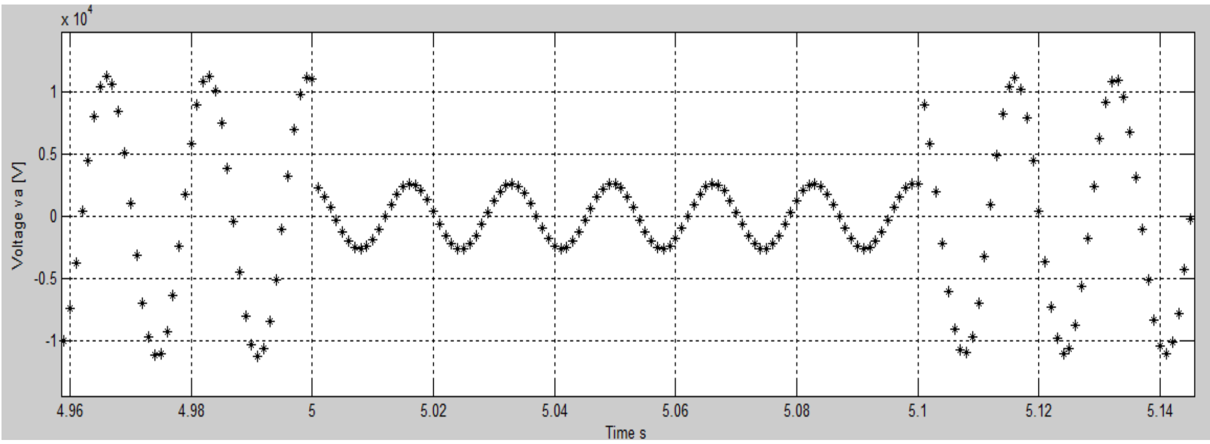

Fig. 5.14: Data stored in database of stator voltage va [V] before, during and after the fault

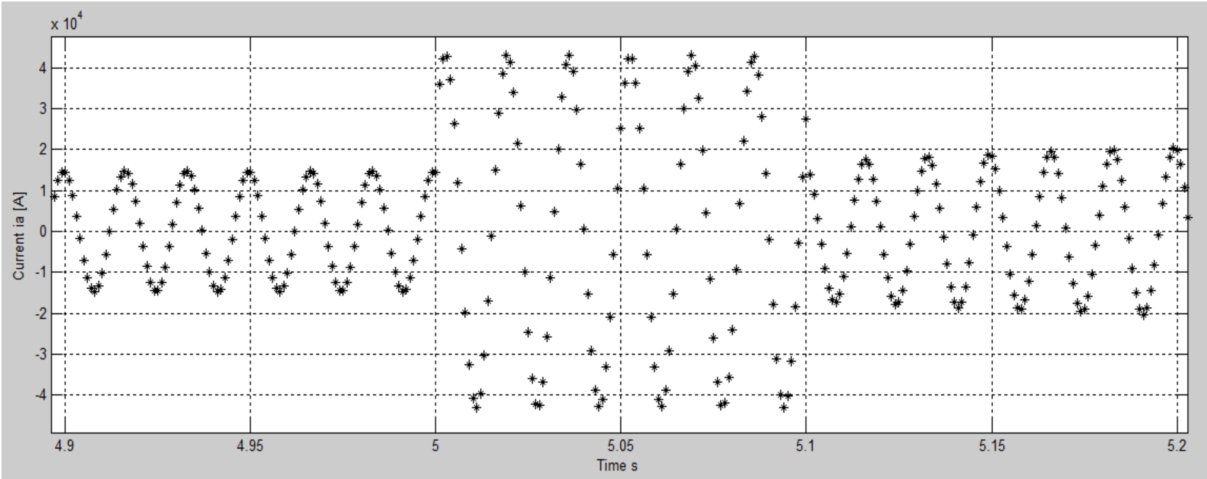

Fig. 5.15: Data stored in database of stator current ia [A] before, during and after the fault

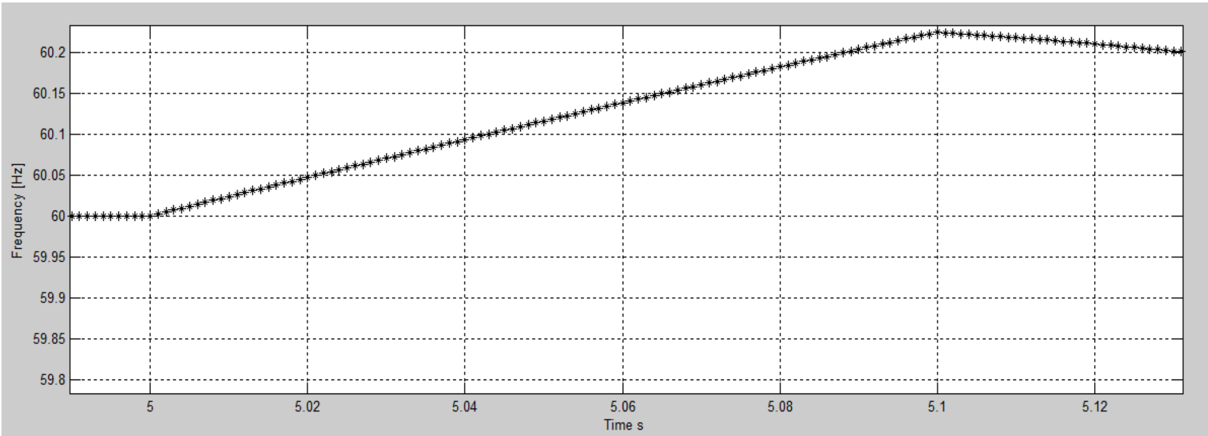

Fig. 5.16: Data stored in database of frequency [Hz] before, during and after the fault

5.4 Data aqcuisation and control system of power plant over internet network

Fig. 5.17 show over all diagram of the data acquisition and control system of the plant. Two control processes were performed over the network. First process is PID control of the gate servo motor of the turbine. The second control process is the power system stabilizer PSS of the excitation system. To perform these control processes a new node, *Controller node*, was added to the network. See Fig. 5.18.

Controller node (node 4) recieves the required data from data acquisition node (node 1) and perform the control processes then sends the resulting control signals to actuator node (node 2) which, in turn, converts signals to analog form and sends them to the plant.

Fig. 5.19 and Fig. 5.20 show the network output control signals during and after the fualt, where Fig. 5.19 shows the network PID control signal of the hydrualic turbine gate servomotor, while Fig. 5.20 shows the network power system stabilizer control signal of the excitation system.

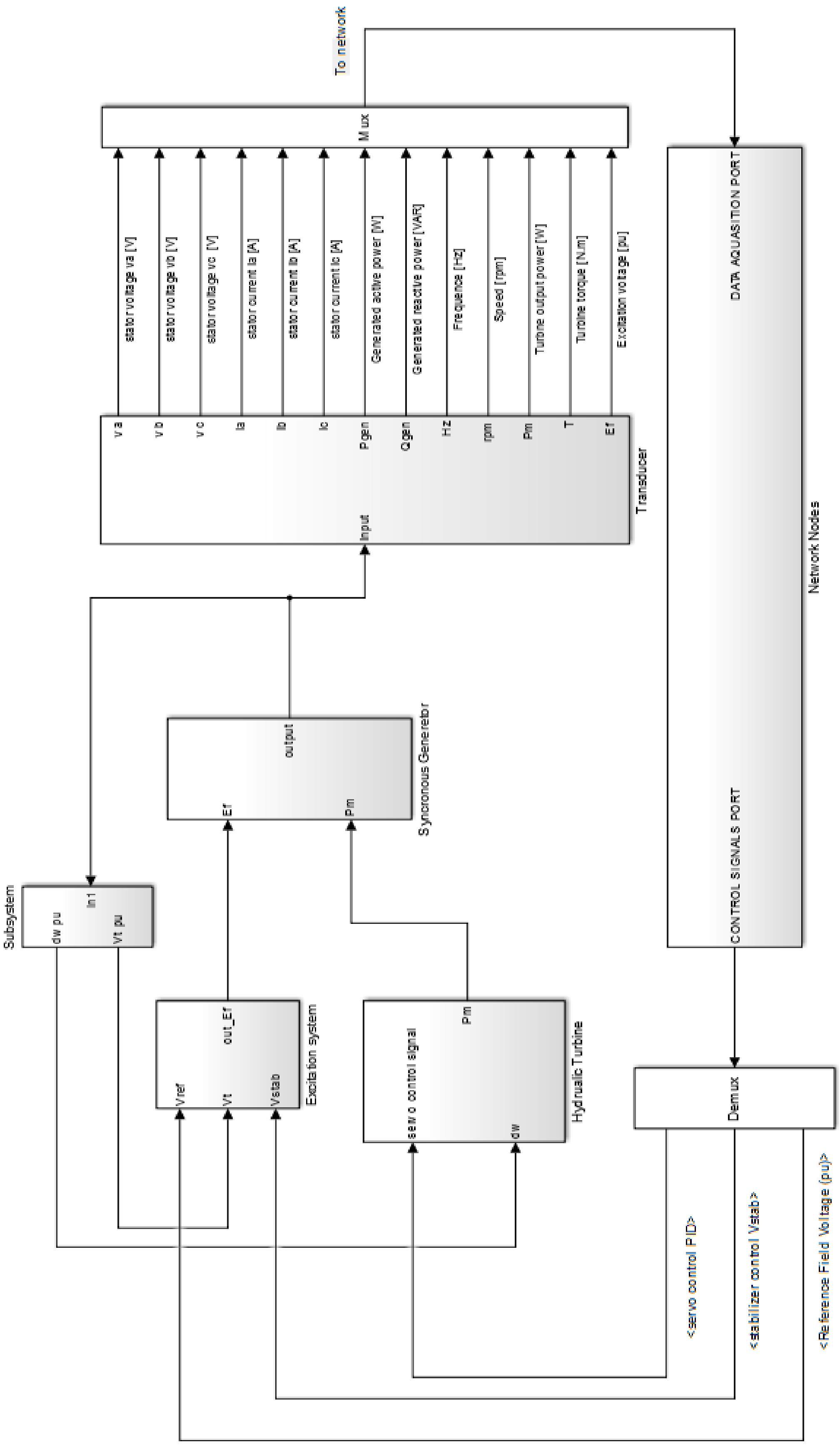

Fig. 5.17: Over all diagram of the data acqusition and control system of the plant

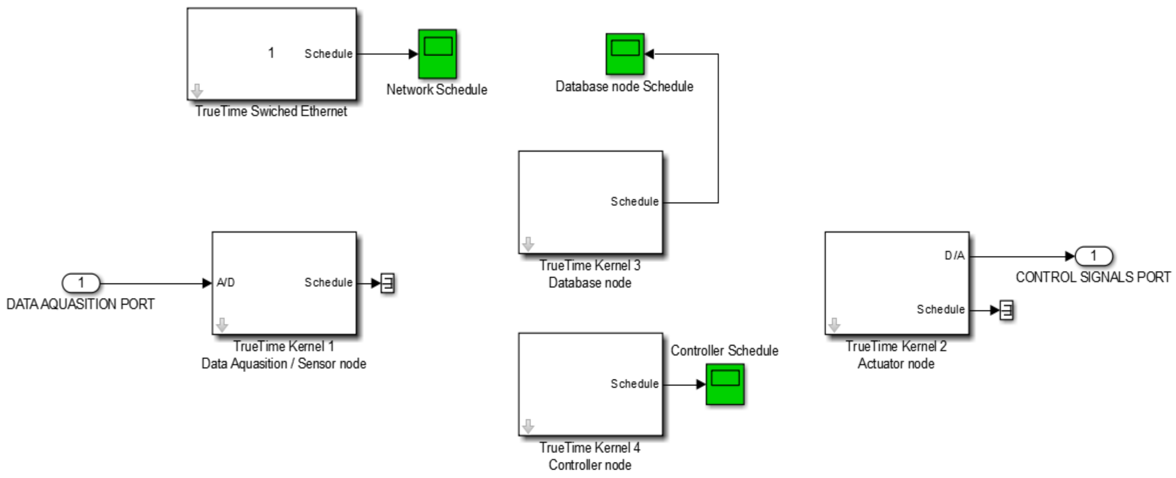

Fig. 5.18: Inside the network subsystem of the data acquisition and control system

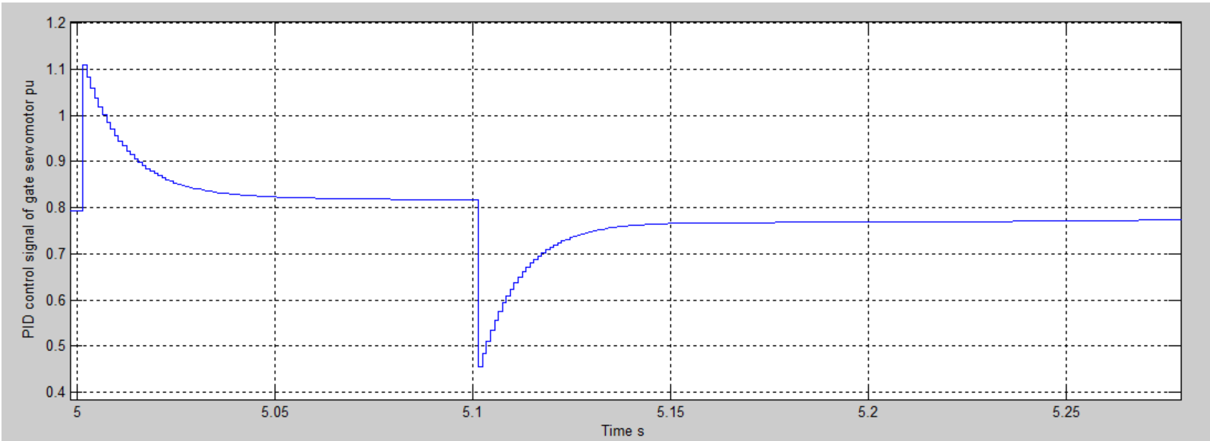

Fig. 5.19: Network PID control signal of gate servomotor of the turbine

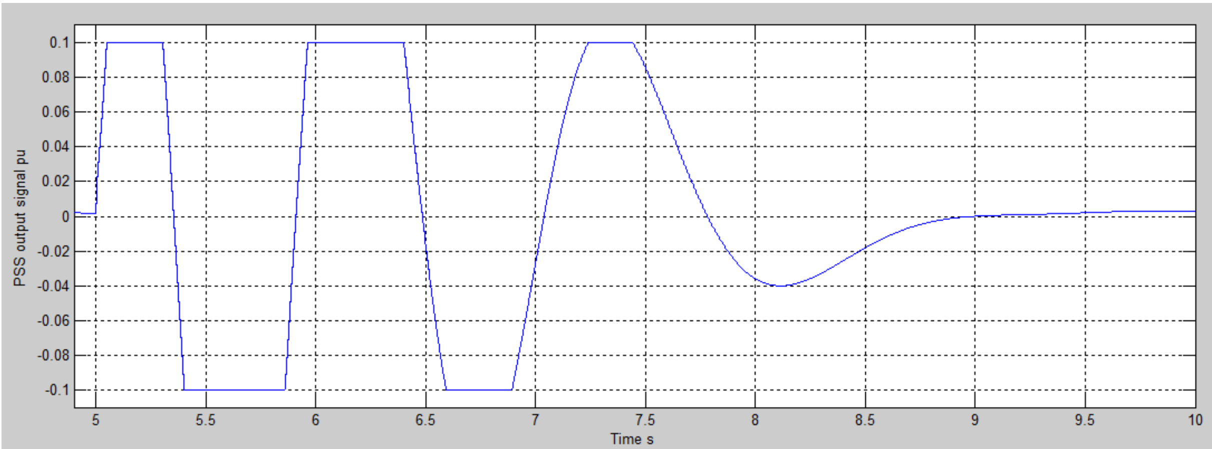

Fig. 5.20: Network PSS control signal

6 CONCLUSION

In this work, a data acquisition and control system of hydroelectric power plant using internet techniques model was developed. The modeled plant consists of hydraulic turbine and synchronous generator with excitation system.

Two synchronous generator models, steady state model and transient model, were simulated using qd rotating reference frame. The modeled generator is connected to infinite bus (infinte grid), Thevenin's equivalent circuit was considered to represent the infinite bus and generator connection. A transient stability study during three phase fault at generator terminals was performed, and the effect of using power system stabilizer on the system stability was discussed.

TRUETIME Matlab library was used to simulate the internet network and to build up a data acquisition and control system of the hydropower plant. TrueTime simulink library was developed by the Department of Automatic Control, Faculty of Engineering, Lund University in Sweden. Switched Ethernet network was used to acquire data from the plant and to send back the control signals.

Four simulation projects were applied; the first project is steady state model of synchronous generator. In this project, the results of steady state operation of synchronous generator during small changes of input power and excitation voltage were shown. The considered generator in first project is connected directly to infinite grid.

In the second project, the transient model of synchronous generator with excitation system model and hydraulic turbine model were applied. The simulated excitation system is DC exciter type excitation system with considering saturation characteristic. Non-linear hydraulic turbine model was applied with PID control of the gate servomotor. The generator transient status after implementing three phase fault on generator terminals was discussed in this project. Also the effect of using power system stabilizer on the system stability was discussed in this project.

In the third project, switched Ethernet network type of TrueTime library network models was used to build up a data acquisition system of the hydropower power plant system model developed and discussed by second project. Results of acquired transient status data during and after the fault when using sampling time of 0.001s of the DACs were shown. In this project three reference values can be adjusted via the network, these reference values are the reference speed value, reference power of the hydraulic turbine value and reference excitation voltage value.

In addition to adjust reference values in the fourth project, two control processes over the network were performed, the control processes are the governor control system of the hydraulic turbine process, and the power system stabilizer process of the excitation system. To perform the control processes, a controller node was added to the switched Ethernet network nodes. In this project, results of using networked control system to control the hydraulic turbine and the excitation system were shown.

BIBLIOGRAPHY

[1] CHEE-MUN ONG. *Dynamic Simulation of Electric Machinery Using Matlab/Simulink*, Prentice hall PTR, 1998, ISBN: 0-13-723785-5.

[2] HASE, Y. *Handbook of Power System Engineering*, John Wiley & Sons, 2007. ISBN: 139978-0-470-02724-4 (HB)

[3] Sattouf, M. Simulation Model of Hydro Power Plant Using Matlab/Simulink, *Int. Journal of Engineering Research and Applications*, ISSN : 2248-9622, Vol. 4, Issue 1(Version 2), January 2014, pp.295-301.

[4] VISIOLI, A. *Practical PID Control,* Springer-Verlag London Limited, 2006. ISBN: 1-84628-585-2.

[5] KUNDUR, P. *Power System Stability and Control*, McGraw-Hill, 1994. ISBN: 0-07-035958-X.

[6] GRIGSBY, L.L. *Power System Stability and Control, Third Edition*, Taylor & Francis Group, LLC, 2012, CRC Press. ISBN: 978-1-4398-8321-1.

[7] MACHOWSKI, J., BIALEK, J.W., BUMBY, J.R. *Power System dynamics, Stability and Control, Second Edition*, John Wiley & Sons 2008. ISBN: 978-0-470-72558-0.

[8] AWAD, M.L. *Modeling of Synchronous Machines for System Studies*, Doctoral Thesis, Department of Electrical and Cornputer Engineering, University of Toronto, 1999.

[9] HRISTU-VARSAKELIS, D., LEVINE, W. *Handbook of Networked and Embedded Control Systems*, Birkhauser Boston 2005. ISBN: 10 0-8176-3239-5.

[10] WANG, F.Y., LIU, D. *Networked Control Systems Theory and Applications*, Springer-Verlag London Limited 2008. ISBN: 9781848002142.

[11] AUSTERLITZ, H. *Data Acquisition Tecliniques Using PCs, Second Edition*, Elsevier Science (USA) 2003, 1991. ISBN: 0-12-068377-6.

[12] DORT, R.C., BISHOP, R.H. *Modern Control Systems Solution Manual, Eleventh Edition*, Pearson Education, Upper Saddle River 2008. ISBN: 9780132270298.

[13] KUAMR, s., MOHAMMAD, s. *PC Based Data Acquisition System*, Diploma Thesis, Electronics & Communication Department, National Institute of Technology, Rourkela, India.

[14] KALAITZAKIS, K., KOUTROULIS, E., VLACHOS, V. Development of a data acquisition system for remote monitoring of renewable energy systems, *Measurement* 34 (2003) pp.75–83. Elsevier 2003.

[15] NIEVA, T. *Remote Data Acquisition Of Embedded Systems Using Internet Technologies: A Role-Based Generic System Specification*, Doctoral Thesis N. 2388 (2001), Présentéé Au Departement D'informatique, École Polytechnique Fédérale De Lausanne, 2001.

[16] IEEE-SA Standard Board, *IEEE Standard for Ethernet,* IEEE Std 802.3-2012.

[17] IEEE Standards Board, *IEEE Recommended Practice for Excitation System Models for Power System Stability Studies*, IEEE Std 421.5-1992.

[18] ZEA, A. A. *Power System Stabilizers for The Synchronous Generator Tuning and Performance Evaluation*, Master of Science Thesis, Department Of Energy and Environment Division Of Electric Power Engineering Chalmers University Of Technology, Goteborg, Sweden 2013.

[19] KOTHARI, M. L., NANDA, J., BHATTACHARYA, K. Discrete mode power system stabilisers, *IEE PROCEEDINGS-C*. Vol. 140, No. 6, NOVEMBER I993, pp. 523-531. IEE 1993.

[20] CERVIN, A., HENRIKSSON, D., LINCOLN, B., EKER, J., ÅRZÉN, K. E. How Does Control Timing Affect Performance? Analysis and Simulation of Timing Using Jitterbug and TrueTime, *IEEE Control Systems Magazine*, June 2003, pp.16-30. ISSN: 0272-1708. IEEE 2003.

[21] CERVIN, A., HENRIKSSON, D., OHLIN, M. *TRUETIME 2.0 beta—Reference Manual*, Department of Automatic Control, Lund University, June 2010.

[22] CHOO, Y. C., MUTTAQI, K. M., NEGNEVITSKY, M. Modeling Of Hydraulic Governor-Turbine For Contrlo Stabilisation, *ANZIAM J. 49 (EMAC2007)* pp. C681-C698, 2008.

[23] CERVIN, A., HENRIKSSON, D., ANDERSSON, M., ÅRZÉN, K. E. TRUETIME: Simulation Of Networked Computer Control Systems, *Preprints of the 2nd IFAC Conf. on Analysis and Design of Hybrid Systems* (Alghero, Italy), 7-9 June 2006, pp. 272-273.

[24] TrueTime: Simulation of Networked and Embedded Control Systems, Matlab/Simulink Library, Lund University, avialable at: http://www.control.lth.se/truetime/.

[25] ODOM, W. *Cisco CCENT/CCNA ICDN1 100-101 Official Cert Guide, Academic Edition*, Cisco Press, Pearson Education 2013. ISBN: 978-1-58714-485-1.

CURRICULUM VITAE

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COMPUTER SKILLS

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ABSTRACT

Hydropower has now become the best source of electricity on earth. It is produced due to the energy provided by moving or falling water. History proves that the cost of this electricity remains constant over the year. Because of the many advantages, most of the countries now have hydropower as the source of major electricity producer. The most important advantage of hydropower is that it is green energy, which mean that no air or water pollutants are produced, also no greenhouse gases like carbon dioxide are produced which makes this source of energy environment-friendly. It prevents us from the danger of global warming.

Using internet techniques to control several hydroelectric plants has very important advantages, as reducing operating costs and the flexibility of meeting changes of energy demand occurred in consumption side. Also it is very effective to confront large disturbances of electrical grid, such as adding or removing large loads, and faults. In the other hand, data acquisition systems provides very useful information for both typical and scientific analysis, such as economical costs reducing, fault prediction systems, demand prediction, maintenance schedules, decision support systems and many other benefits.

This thesis describes a generalized model which can be used to simulate a data acquisition and control system of hydroelectric power plant using MATLAB/SIMULINK and TrueTime simulink library. The plant considered consists of hydropower turbine connected to synchronous generator with excitation system, and the generator is connected to public grid.

Simulation of hydropower turbine and synchronous generator can be done using various simulation tools, In this work, SIMULINK/MATLAB is favored over other tools in modeling the dynamics of a hydropower turbine and synchronous machine. The SIMULINK program in MATLAB is used to obtain a schematic model of the hydropower plant by means of basic function blocks. This approach is pedagogically better than using a compilation of program code as in other software programs .The library of SIMULINK software programs includes function blocks which can be linked and edited to model. Either Simulink Real-Time library or TrueTime library can be used to build and simulate internet and real time systems, in this thesis the TrueTime library was used.

ABSTRAKT

Vodní energie se nyní stala nejlepším zdrojem elektrické energie na zemi. Vyrábí se pomocí energie poskytované pohybem nebo pádem vody. Historie dokazuje, že náklady na tuto elektrickou energii zůstávají konstantní v průběhu celého roku. Vzhledem k mnoha výhodám, většina zemí nyní využívá vodní energie jako hlavní zdroj pro výrobu elektrické energie.Nejdůležitější výhodou je, že vodní energie je zelená energie, což znamená, že žádné vzdušné nebo vodní znečišťující látky nejsou vyráběny, také žádné skleníkové plyny jako oxid uhličitý nejsou vyráběny, což činí tento zdroj energie šetrný k životnímu prostředí. A tak brání nebezpečí globálního oteplování.

Použití internetové techniky k ovladání několika vodních elektráren má velmi významné výhody, jako snížení provozních nákladů a flexibilitu uspokojení změny poptávky po energii na straně spotřeby. Také velmi efektivně čelí velkým narušením elektrické sítě, jako je například přidání nebo odebrání velké zátěže, a poruch. Na druhou stranu, systém získávání dat poskytuje velmi užitečné informace pro typické i vědecké analýzy, jako jsou ekonomické náklady, predikce poruchy systémů, predikce poptávky, plány údržby, systémů pro podporu rozhodování a mnoho dalších výhod.

Tato práce popisuje všeobecný model, který může být použit k simulaci pro sběr dat a kontrolní systémy pro vodní elektrárny v prostředí Matlab / Simulink a TrueTime Simulink knihovnu. Uvažovaná elektrárna sestává z vodní turbíny připojené k synchronnímu generátoru s budicí soustavou, generátor je připojen k veřejné elektrické síti.

Simulací vodní turbíny a synchronního generátoru lze provést pomocí různých simulačních nástrojů. V této práci je upřednostňován SIMULINK / MATLAB před jinými nástroji k modelování dynamik vodní turbíny a synchronního stroje. Program s prostředím MATLAB SIMULINK využívá k řešení schematický model vodní elektrárny sestavený ze základních funkčních bloků. Tento přístup je pedagogicky lepší než komplikované kódy jiných softwarových programů. Knihovna programu Simulink obsahuje funkční bloky, které mohou být spojovány, upravovány a modelovány. K vytvoření a simulování internetových a Real Time systémů je možné použít bud‘ knihovnu simulinku Real-Time nebo TRUETIME, v práci byla použita knihovna TRUETIME.